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I. Fehér

A. Andrási

S. Makra

TEN YEARS OF THE HEALTH PHYSICS DEPARTMENT OF THE CENTRAL RESEARCH INSTITUTE FOR PHYSICS

HUNGARIAN ACADEMY OF SCIENCES

CENTRAL RESEARCH INSTITUTE FOR PHYSICS

BUDAPEST

TEN YEARS OF THE HEALTH PHYSICS DEPARTMENT OF THE CENTRAL RESEARCH INSTITUTE FOR PHYSICS

I. Fehér, A. Andrási and S. Makra
Central Research Institute for Physics, Budapest, Hungary

The first ten years after the founding of the Central Research Institute for Physics in Budapest in 1950 saw a continuous growth in the importance of research in the fields of nuclear physics and radioactive isotopes. These years were marked first by the construction of several particle accelerators and a laboratory equipped for work with tracer levels of isotopes, and culminated in the building of a 2 MW WWR-S experimental nuclear reactor, which became operational in 1959. A zero-power reactor and a hot laboratory for isotope production were also provided, so that by the end of the decade the number of establishments working with radiations had diversified considerably and the sources of radiation hazard had multiplied correspondingly. Inevitably such development meant that more and more people were employed on work involving these hazards, and by 1959 there were already 200.

During this period radiation protection had been the responsibility of each department concerned, but it had become clear that such an arrangement was not adequate to deal with the many complicated and fundamental problems of radiation protection in the Institute. Although health physics control of the experimental reactor was to remain in the hands of a special team, it was decided to set up a group to direct radiation control operations in the other departments and to provide overall guidance in these operations for the whole Institute. The small group which was formed was reorganized in the summer of 1960 as the Health Physics Department.

For the first five years the work of the Department /also referred to as the HPD/ was devoted to the creation of an efficient radiation protection service and the development of suitable methods for radiation monitoring and control. With time, however, the opportunity arose for research work into outstanding problems encountered during the developmental years, so that original contributions could be made to the field of radiation protection.

1. FIRST STEPS (1960-1965)

The immediate tasks of the HPD on its formation were the preparation of a study analyzing the state of radiation hazard in the Institute and the solution of problems that emerged from the study. It appeared, for example, that there was an urgent need for more reliable personnel dosimetry /including monitoring of internal contamination/ and for more strict dosimetric control of working places. This meant that suitable dosimeters and activity-measuring devices had to be acquired and calibrated in a very short time. The continuous running of the experimental reactor and the scale of isotope production required a comprehensive monitoring network for control of the environment. It also became the task of the HPD to provide for the central registration and storage of radioactive sources in the Institute, as well as the collection and handling of radioactive wastes.

An outline of the activities of the HPD in these first five years is presented in the following sections. Many of the details relating to these activities can be found in publications originating from the Department. A list of these publications is given at the end of the booklet. Attention should be drawn particularly to "Measurement methods in radiation protection" /1964/, which contains an account of the principal methods in use within the Department.

1.1. Personnel dosimetry

One of the findings of the HPD's initial survey was that the pocket ionization chambers then used in the Institute were not sufficiently reliable. For this reason systematic film dosimetry was introduced from January 1961. At first, data both from pocket chambers and film dosimeters were recorded in the central personnel dose register, but once the reliability of the latter method had been clearly established the central recording of pocket chamber measurements was discontinued. Direct-reading pocket chambers were still used, however, as a means of personal monitoring.

Since operators of the Cockroft-Walton accelerator had been found to receive above permissible doses of soft X-rays, a film dosimetrical method based on filter analysis was developed for measuring this radiation, to complement the determinations of high energy gamma rays. Film dosimeters were also modified for measurements of beta dose; their measuring range was extended by combining sensitive with insensitive films which cover the range from permissible dose to emergency - level dose. A special film dosimeter was used for monitoring the radiation exposure of the hands during isotope production.

One of the early investigations of the HPD was into the considerable contamination of laboratories during the production of ^{131}I from TeO_2 targets and the preparation of various isotopes from fission products. On the assumption that internal incorporation was comparable to the level of the external irradiation, the ^{131}I burden of the thyroids of those working in the laboratories was measured with a scintillation counter, and in some cases was indeed higher than the maximum permissible dose. It was discovered that dust originating from the TeO_2 targets contained radioactive tellurium isotopes and was a major source of contamination in addition to the radioiodine vapours.

Because other isotopes constituted incorporation hazards, steps had to be taken to ensure proper surveillence. At first a coprecipitation method for determining the total beta activity of urine was used,then in 1962 the decision was made to design a whole body counter for direct measurement of internal contamination. This counter /IAEA code number HY 2.1/ was ready for operation by the summer of 1964 and has solved the problem of systematic monitoring of internal radiation dosage. The equipment is shown in Fig. 1.

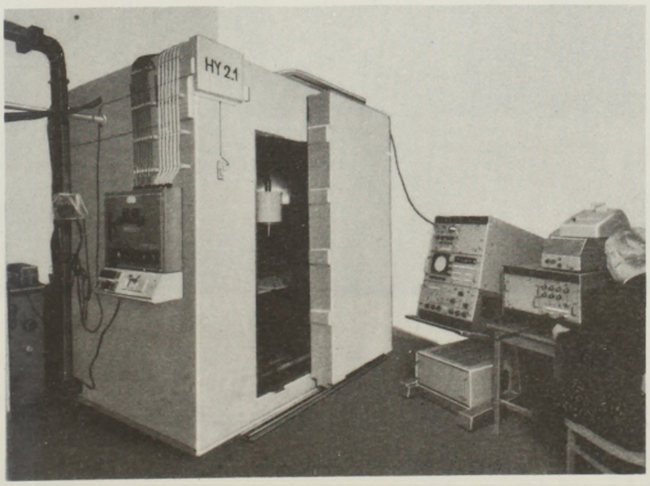


Fig. 1

Whole body counter

1.2. Radiation monitoring in working places

The radiation protection control of laboratories was performed by various fixed and portable dose-rate meters and contamination-measuring instruments that had been purchased by the HPD. The main task was, therefore, the building up of a collection of instruments for calibrating the monitoring devices. In 1960 only some standard ^{226}Ra sources, a 200 kV X-ray machine and some Siemens dosimeters were available for this purpose, and they did not meet the requirements of the situation. The HPD accordingly developed the following instruments:

- a scintillation beta-gamma coincidence counter,
- a flow-type 4π - proportional beta counter /shown in Fig.2./
- a 4π γ- ionization chamber

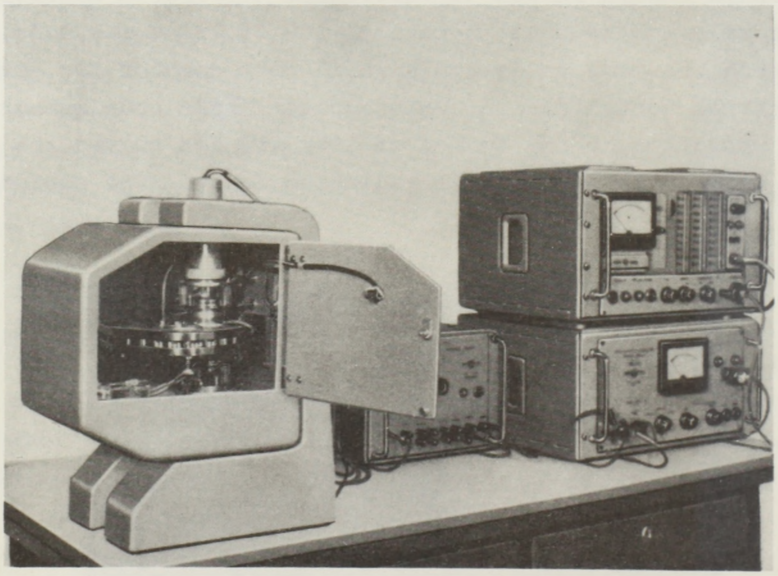


Fig. 2

4π proportional beta counter

By the help of these instruments standard sources of ^{131}I, ^{198}Au, ^{56}Mn, ^{32}P, ^{60}Co,etc. could be prepared for calibrating the activity meters.

A manganese sulphate bath method was devized for measuring the yield of neutron sources. As a further aim in the field of dose standardization was the introduction of beta dosimetry, an extrapolation ionization chamber was also built /Fig. 3/. Using this instrument, the absolute beta dose rates of ^{204}Tl and ^{90}Sr sources were measured so that the sources could be used for calibration of beta film dosimeters.

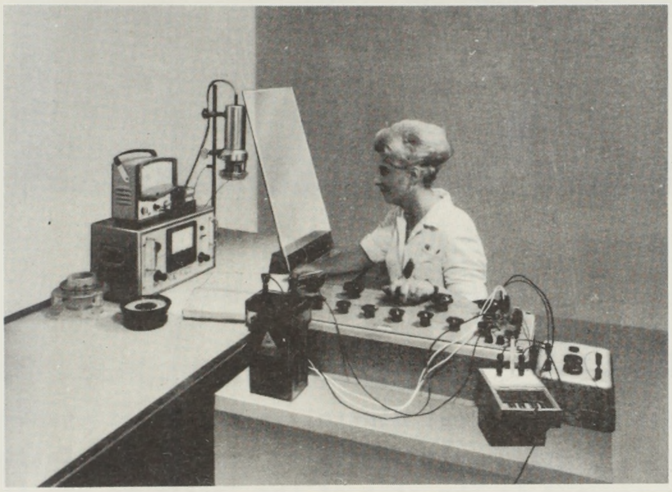


Fig. 3
Extrapolation ionization chamber

The equipment for quantitative and qualitative activity analysis and for measurement of radioactive contamination was initially modest. Besides purchasing a set of beta activity measuring devices and well-type NaI/Tl/ scintillation counters the department developed for itself

- a gas flow-type 2π counter
- a CsI/Tl/ scintillation alpha and beta spectrometer
- a low background beta counter
- a continuously operating gas-activity ionization chamber with gamma compensation /50 litre sensitive volume/.

Original work that was carried out in the department included: investigation of the average energy of bremsstrahlung X-radiation by absorption measurement around the Cockroft-Walton accelerator; working out of a method for the preparation of large-surface beta radiation sources; and, in 1961, the development of surface barrier silicon semiconductor detectors sensitive to alpha particles, protons and fission products /see Fig. 4/. The semiconductor detectors were used for the standardization of fission neutron sources and for measurements of thermal neutron flux.

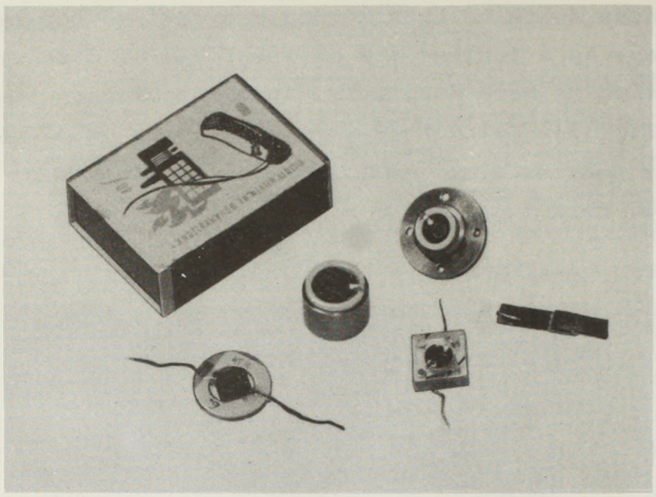


Fig. 4
Semiconductor detectors

1.3. Environmental control

Systematic environmental control in the Institute began in the second half of 1961. Continuously operating aerosol and fallout sampling stations were constructed in the area of the Institute and at several points in Budapest, and a station for continuous monitoring of the gamma background level was also established.

Investigation of the contamination caused by the large-scale atmospheric nuclear weapon tests of 1961 and 1962 served as a basis for planning the multiple station environment control network that is currently operated by the HPD. One of the facets of this contamination that was determined was the relationship between the ^{131}I content of cattle thyroid, the aerosol and the fallout concentration. Estimation of the local dose of radioactive particles was achieved by autoradiographic techniques.

1.4. Isotope storage

The HPD was responsible for the planning of a central store for the isotopes used in the Institute. There are arrangements for holding beta sources in the channels of a concrete block, and gamma sources in cells equipped with manipulators. Fissionable materials, neutron sources and tritium sources are stored separately in specially protected cells. Means are available for the repackaging and for the leakage control of all these materials. A view of part of the store is shown in Fig. 5.

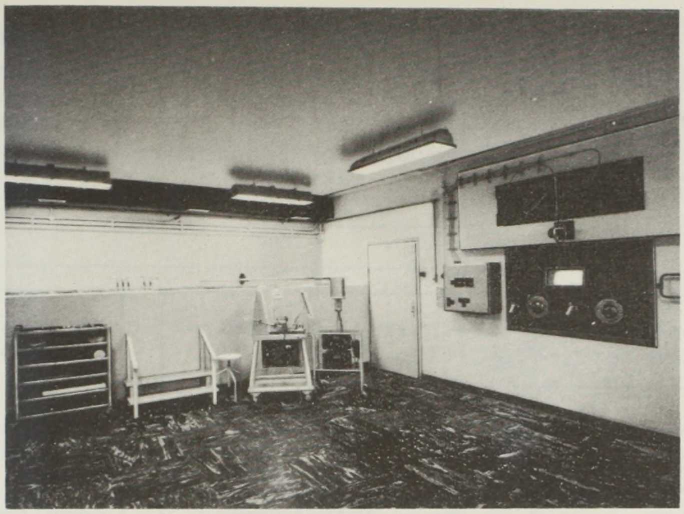
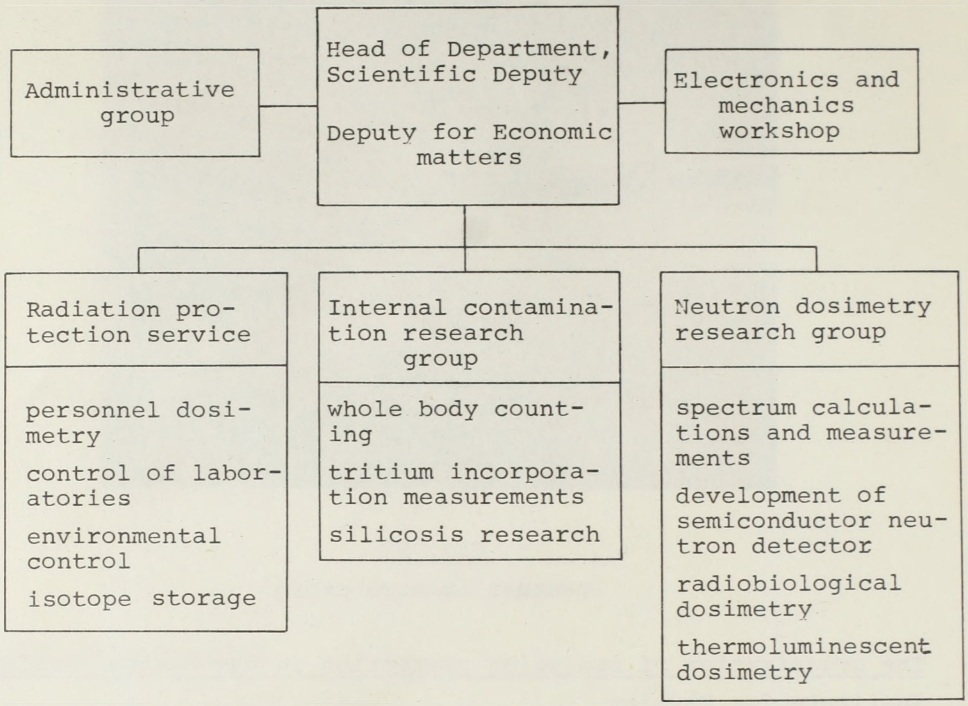


Fig. 5
Central isotope store

1.5. The organization of radiation protection in the Central Research Institute for Physics

The organizational structure and responsibility system for radiation protection are clearly defined in a list of statutes drawn up by the HPD. While arrangements for personnel dosimetry, environmental monitoring and isotope circulation are undertaken by the HPD itself, day-to-day controls in the laboratories is the responsibility of the individuals working there. In the smaller departments a single person is appointed to supervize radiation protection measures, whereas a whole group has this task at the experimental reactor. The HPD makes periodic checks of these activities. Provision is also made for inspection outside working hours, and procedures have been laid down for procedure in the event of extensive radiation accidents.

The structure of the HPD has been determined by the range of its activities. During its first five years of operation all department members were engaged on the development and maintenance of the radiation protection service. In the following period the two functions were separated. The present organizational form became established with the emergence of two main lines of departmental research - investigation of biological incorporation of radioactive materials, and neutron dosimetry.



2. THE PERIOD (1966-1970)

Within the organizational framework that evolved in its first five years the HPD has continued its efforts to provide a modern approach to health physics. Since supervisory activities of the Department are its most fundamental responsibilities, and because there are always new developments in this area, they again figure in the following outline of the more recent work of the HPD.

2.1. Supervisory activities of the Radiation Protection Service

Personnel dosimetry

As mentioned before, film dosimetry is the most important single technique for controlling the external dosage of persons working in the Institute. The dosimetric measurement of low and high energy gamma radiation, thermal neutrons and high energy beta radiation is carried out using bags provided with suitable filters. At present about 500 persons are wearing such dosimeters. Calibrated, direct-reading ionization chamber dosimeters are also available for self-monitoring by individual workers. Where certain parts of the body, such as the hands, are subject to especially great exposure hazard it is hoped that the film dosimeters used at present can be replaced soon by thermoluminescent dosimeters. People working under the hazard of fast neutron exposure are provided with nuclear emulsion track film dosimeters. Special personnel dosimeters for measuring gamma nad neutron radiation have been developed for use in places where the chances of radiation accidents are especially high. One of these accident dosimeters is shown in Fig. 6.

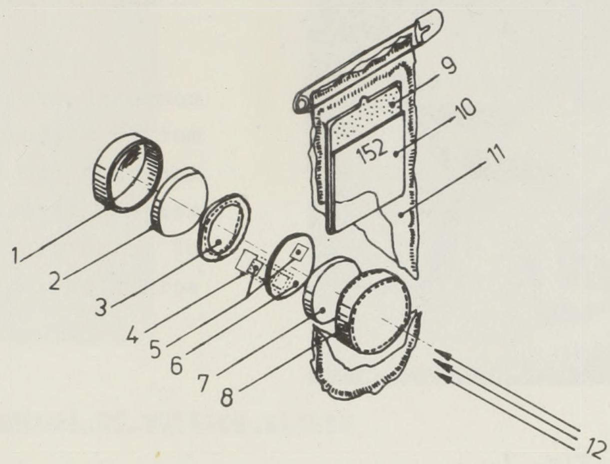


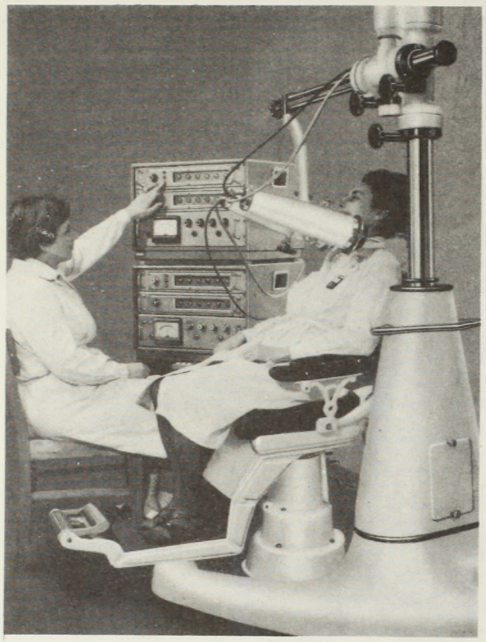
Fig. 6

Accident dosimeter

1/ Cadmium box bottom, 2/ P pellet,
3/ Tl glass in a plexiglass ring,
4/ thick Au foil, 5/ thin Au foil,
6/ Cadmium disc, 7/ S tablet,
8/ Al box lid, 9/ dosimeter film,
10/ Pb filter, 11/ PVC sack,
12/ direction of irradiation

In this connection, a well-proven method is available for determining from a sample of hair the neutron dose received by a person involved in a criticality accident.

The above techniques effectively cover the requirements for monitoring of the various external radiations and their wide range of energy and dose as they exist in the Institute. Monitoring of internal radiation contamination with the gamma-radiating isotopes is carried out mainly with the help of the HPD's whole body counter, the only major exception in this respect being tritium contamination. Special measuring instruments were constructed only for a few specific isotopes, such as for the direct determination of ^{131}I and ^{125}I activity in the thyroid gland. Fig. 7. shows the arrangement of the latter equipment.



Indirect measurement of internal contamination is also carried out. Urine analysis by gamma spectrometry without any chemical processing has been established. For high sensitivity and low background measurements of 500-2000 ml samples the apparatus shown in Fig. 8. is used.

There is the possibility of computer evaluation of such spectrometric measurements. Exposure resulting from the handling of tritium targets is also measured on the basis of urine activity, but by a liquid scintillation method.

Fig. 7.
^{131}I and ^{125}I activity meter

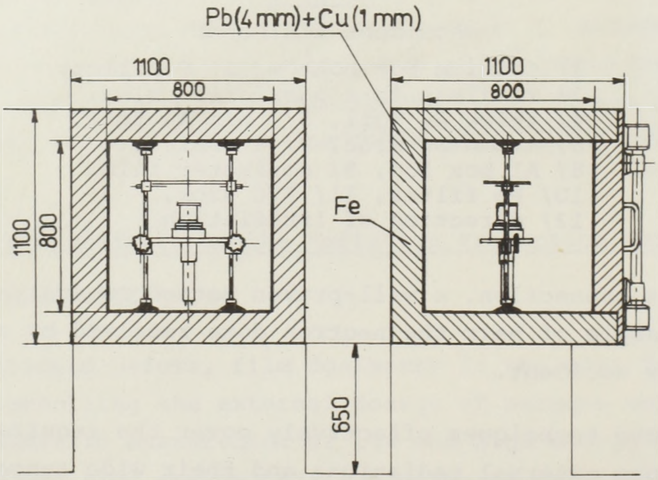


Fig. 8.
Low background gamma spectrometer

One of our aerosol-measuring instruments has been developed as another indirect means of internal monitoring. This is the personal aerosol sampler for multiple usage, which is produced in the light, portable form shown in Fig.9.

Fig. 9.
Personal aerosol sampler

Radiation protection control of working places

Monitoring of the Institute's laboratories is carried out with measuring instruments supervized by the individual departments concerned, as well as by instruments installed by the HPD. Those responsible for radiation protection in the laboratories work under the professional guidance of the HPD, and there are, in addition, the periodic local inspections. These tasks require a vast number of measuring instruments; some of the more important are described in the following paragraphs.

Two different aerosol-measuring instruments are used for monitoring laboratories in which there is a hazard of internal contamination of staff and for monitoring the air passing through laboratory exhaust systems. These are: a portable aerosol sampler of intermittent operation; and an aerosol sampler and analyzer capable of continuous operation /Fig. 10./. Both of these aerosol samplers are equipped for determining the activity of either radioactive dust or vapour, e.g. ^{131}I.

Thin-walled parallel plate ionization chambers were constructed for determining the gamma and beta dose rates in rubber-gloved manipulation chambers. These ensure the constant control of hand exposure during work.

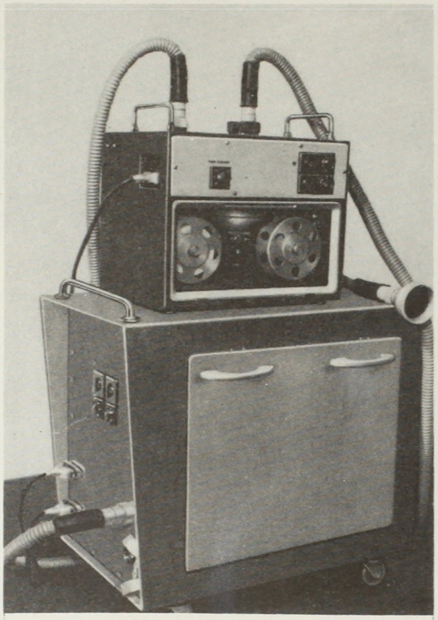


Fig. 10
Continuous aerosol sampling and measuring device

General monitoring of work-places is achieved with paraffin moderator rem counters developed by the neutron dosimetry working group.

Emergency film dosimeters and neutron accident dosimeters have been installed in places subject to radiation accident hazard so that the circumstances of any accident can be more accurately reconstructed.

Great importance has been attached to spanning the whole spectrum of the possible measuring tasks by the use of portable, battery-fed instruments. By modifying commercially available apparatuses their utility has in many cases been extended. An example is the "Transrate" portable dose rate meter of the "Gamma" Optical Works, which by only slight modification was converted into a device measuring surface contamination over large areas also /as shown in Fig. 11/.

Both measurement of the activity of samples of various origins and their spectrometric determination can be performed, whether alpha, beta or gamma radiation is involved. These measurements can be performed even where activities are very low, and in large-volume samples of low specific activity. Serial measurements of activities can be carried out with the help of automatic sample-changing devices.

The HPD has to carry out the periodical calibration of all radiation monitoring instruments /dosimeters and dose rate meters/ used in the Institute. This calibration is carried out using X-ray equipment and the so-called "irradiation facility", which employs radioactive sources /see Fig. 12/.

Fig. 11
"Transrate" large surface beta detector

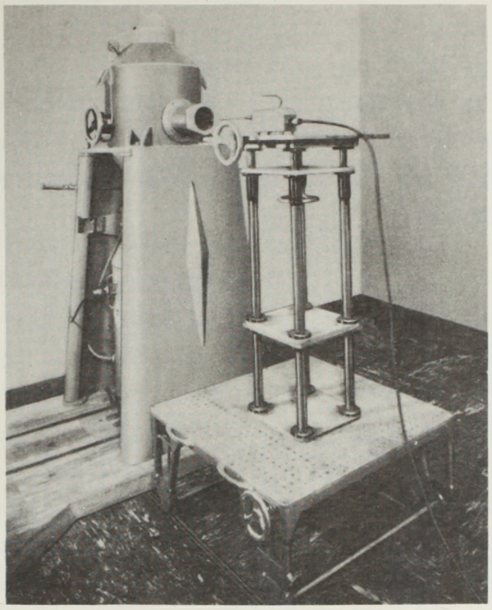


Fig. 12
Calibration irradiation facility

Environmental monitoring

The purpose of the environmental control is to continuously determine, both within and outside the Institute, the degree of radiation hazard that results from work carried out in the Institute. Control includes:

- Monitoring of atmospheric contamination by radioactive aerosols,
- measurement of the radioactivity of effluents released into the public drainage
- continuous checking of gamma dose level at various points within the Institute,
- measurement of the most important meteorological data.

The control stations measuring radioaerosol concentration of the atmosphere consist of a continuously collecting aerosol sampler, from which 24-hour samples are taken for analysis, and a fallout sampling system. One of these stations is shown in Fig. 13. There are six stations within the Institute and four in public areas outside the Institute lying in the path of the prevailing wind. In addition, at a central point in the Institute, an automatic aerosol sampler provided with an indicator signalling any overstepping of a given pre-set level operates day and night. Fig. 14. shows the average daily atmospheric concentration of the radioaerosol measured at one of the control stations in 1969.

Fig. 13
Aerosol measuring station

Radioactivity of the effluent water leaving the area of the Institute is remotely monitored by a system suitable for the continuous measurement and recording of 10^{-5}-10^{-2} microcurie/millilitre gamma activity concentration for ^{137}Cs. When a given level is exceeded there is provision for automatic sampling of the effluent. Continuous time-proportional sampling, and X-ray absorption measurements of the flow-rate of the effluent water are also carried out.

The gamma dose rate is continuously measured with GM-tube probes set up at eight points in the public area of the Institute. Overstepping of the pre-set level of the probes is signalled in the Radiation Protection Service Centre by light and sound alarms.

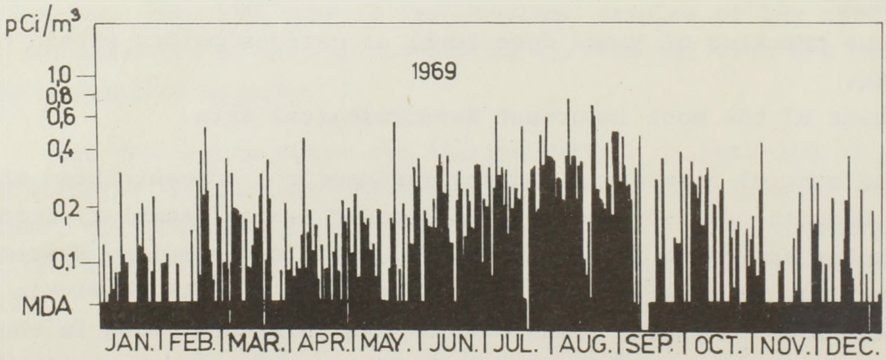


Fig. 14
Average environmental radioaerosol concentrations in 1969

2.2. Research into internal contamination

The problems in this area arose from the production and application of radioactive isotopes in the Institute. Only problems relating to inhalation, which is the most serious of these hazards in the Institute, were given detailed consideration. A number of other mainly medical diagnostical problems were also solved and investigation methods developed by the HPD have since been applied to radiation protection tasks outside of the Institute.

Whole body counting

One of the main objectives in the field of incorporation research has been extend the range of measurement and the applications of the whole body counter put into operation in 1964. The point has been reached where all important measurements can now be obtained in line with modern standards. The most significant features are:

- the tilted-chair geometry, arc geometry, and the so-called scanning geometry with moving detectors, with location of the control and continuous position indicator unit outside of the shielding;
- the use of a mosaic detector for the spectrometric measurement of gamma radiation in the 20-200 keV energy range, with calculation of detector sensitivity on the basis of a simplified pulmonary model;
- a spectrum stabilizer system using a radioactive reference light source built into the large crystal detector, channel stability for the reference signal being 450 $\pm$ 0,1;
- transmission of data by telephone line to the Institute's ICT 1905 computer and for data storage on magnetic tape.

The explicit analytical expression depends on the position and energy coordinates and has been determined semiempirically with respect to point sources for the measuring efficiency of the large crystal detector with the help of an ICT 1905 computer. From this relationship, the characteristic operational parameters of the modified scanning arrangement could be calculated to find the most uniform position dependence in the high energy range, which enabled the optimum measuring geometry to be chosen. Fig. 15 shows one of the results given by this so-called scanning end-stop method. The efficiency calculations were extended to the case of distributed sources, too.

In 1969, the tedious and inaccurate manual evaluation of gamma-spectra gained in the course of whole-body counting of human being was replaced by computer evaluation. In addition to this spectrum analysis, the DASK pro-

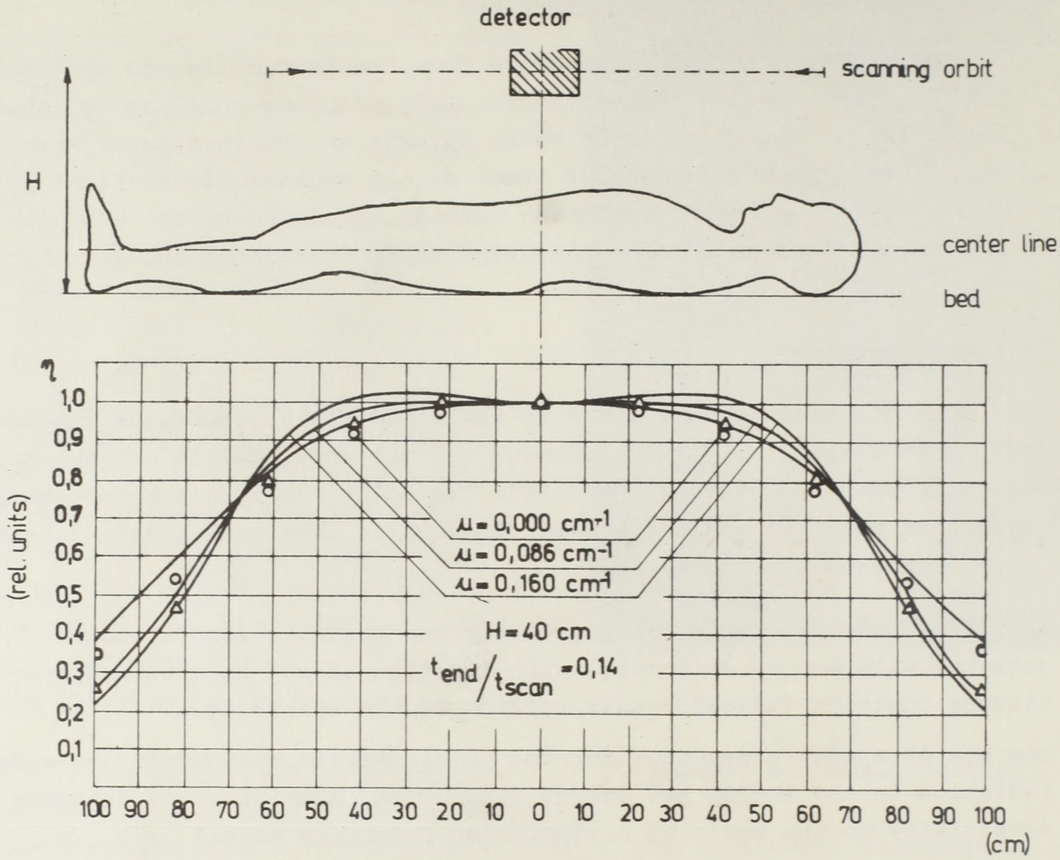


Fig. 15

Longitudinal variation of the relative photopeak efficiency for the scanning "end-stop" method calculated using three different attenuation coefficents

————	calculated curves
o	measured values /μ = 0,000 cm^{-1}/
Δ	measured values /μ = 0,086 cm^{-1}/

cedure performs other useful calculations connected with whole-body counting, and moreover yields data on the equipment's characteristics that can be used to check its correct functioning. The DASK procedure can be used to perform other tasks connected with the application of gamma spectrometry in radiation protection.

The measurement of persons suffering casual incorporation permitted the determination of certain metabolic parameters e.g. the determination of ^{65}Zn retention.

Investigations of the biological incorporation processes of members of the TeO_2-^{131}I system arose in the course of the radiation protection control of ^{131}I production and they comprised experiments on human and animal subjects. The permissible burden of the whole body and the lungs, as well as the permissible concentrations, were calculated for humans with the help of dosimetric data measured in vitro.

The Army Hospital cooperated in a study of the ^{64}Cu metabolism of a patient suffering from Wilson's disease before and during penicillamine treatment, which demonstrated a mobilization of Cu. Another study at the same hospital was on ^{59}Fe absorption in patients treated for burn injuries; these studies established that the iron absorption ability of the patients was reduced.

Measurements by the whole body counter made possible the determination of ^{137}Cs burden resulting from radioactive fallout originating from nuclear weapon tests. Results are shown in Fig. 16.

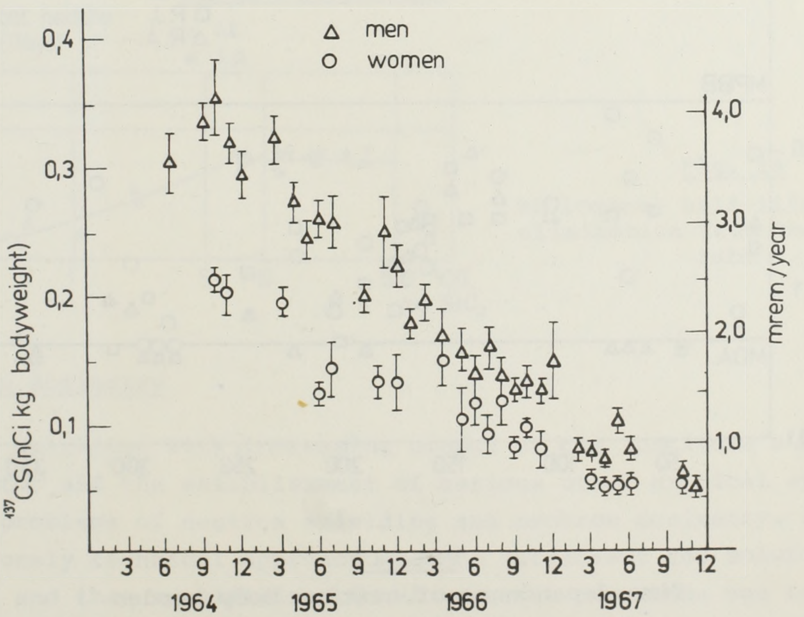


Fig. 16

^{137}Cs body burden of Budapest inhabitants due to nuclear weapon tests

The investigation of tritium incorporation

Initial measurements of the body burden of persons workint with Zr - T targets showed that it varied between 0,1 - 1 times the maximum permissible body burden. /See Fig. 17./ On this basis methods were developed for studying tritium concentration in urine, as well as air and surface contamination. It was here that personal aerosol sampling was applied for the first time. The studies revealed that contamination and incorporation were due to Zr-T particles and not to tritium gas evolving from the target. The aerosol-generating ability of the targets and the size distribution of the resulting particles were investigated using autoradiography and a static sedimentation method. It appeared that the tritium penetrates into the organism through the skin. The preventive measures taken in the light of these findings have meant that the body burden of people working in endangered places does not normally now exceed 0,1-0,2 times the maximum permissible level.

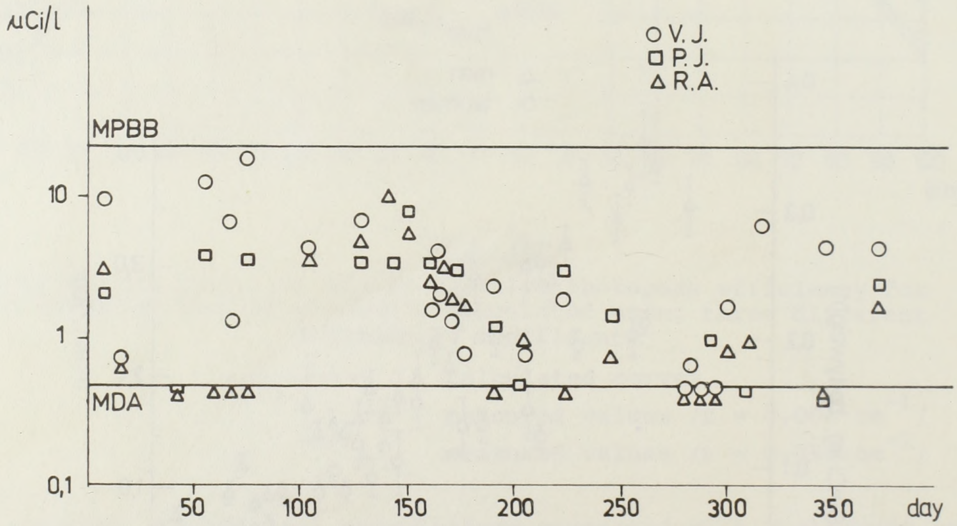


Fig. 17
Time dependence of tritium body burden

Silicosis research

The results of the investigations on the TeO_2-^{131}I system led to the generalization of the carrier-free independent tracer method which was developed for study of the metabolism of particles penetrating the respiratory tract and to the application of the method to research into damage caused by nonradiotoxic dust, particularly silicosis. Quartz dust was labeled with ^{22}Na by a thermal diffusion method. By use of a sedimentation technique it was proved that the amount of labelling of particles which are bigger than 2 μm is proportional to particle volume. Study of the variation of the speed and equilibrium of isotopic exchange with temperature verified that tracing is satisfactorily stable for the purpose of in vivo investigations. The clearance of quartz particles from the lungs was followed in rats in two experimental series of one year each. The biological half-life for lung clearance was found to vary significantly as a function of the quantity of quartz administered into the lung by intratracheal /i.t./ injection as shown in Fig. 18; the clearance following intraperitoneal /i.p./ injection was used as control. On the basis of the experience obtained with the body counter for human beings a small animal counter was constructed for use in these experiments. Retention and excretion data were evaluated by DAS1 and SHES computer programs, which permitted the calculation of essential metabolic constants directly from data given by the counter.

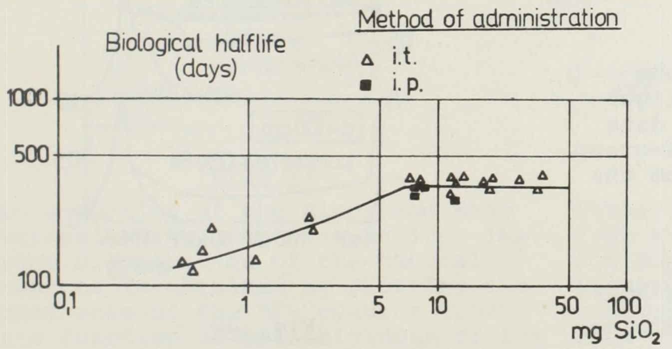


Fig. 18

Biological half-life of quartz elimination from the lungs of rats

2.3. Neutron dosimetry

The operation with increasing output of the Institute's WWR-S nuclear reactor and the establishment of various other critical systems raised many problems of neutron shielding and neutron dosimetry. It turned out that a purely technical approach was not sufficient for solutions of the problems and that a multidirectional research programme was required.

Spectrum calculations and measurements

The thick shielding wall surrounding a reactor considerably widens the energy spectrum of the emergent neutrons; for such shielded reactors a neutron energy range of about 10 MeV-10^{-2} eV is typical. The measurement of neutrons in such a wide range has involved approaches from both the theoretical and the technical angle.

The theoretical work was related to the calculation of the spectra of neutrons penetrating various shielding layers. Spectra for plane geometry have been calculated for fission neutrons and for the WWR-S reactor spectrum passing through water, polyethylene, iron, lead, concrete, concrete+iron, and concrete+boron shieldings. Figs. 19 and 20 show some characteristic results.

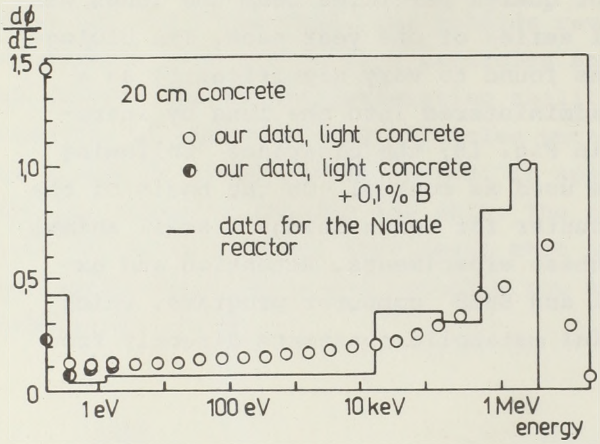


Fig. 19

Spectrum of reactor neutrons penetrating through a 20 cm thick light concrete wall, on the basis of data obtained at the Institute by 26-group calculations and data taken from the literature

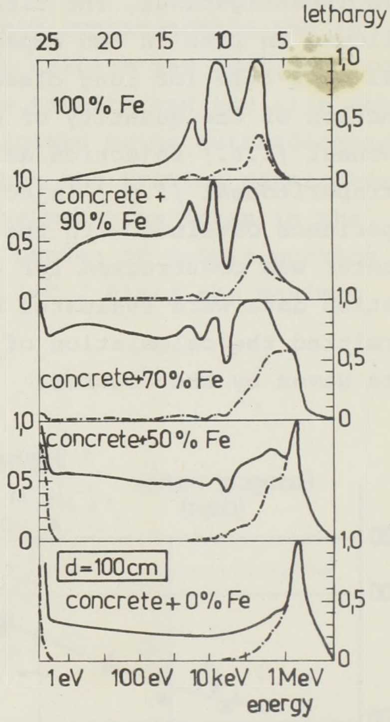


Fig. 20

Spectra of fission neutrons penetrating through concrete-iron layers of different composition. Full line: flux spectrum; dotted line: dose spectrum. The iron concrete ratios are given as weight percentages

On the basis of the results, quantities which have direct application in dosimetry have been determined; e.g. average neutron energies, readings of different dosimeters irradiated by different spectra, the dose fractions of slow and intermediate neutrons. Such calculations have been utilized in the design of various measuring systems and in the establishment of their characteristics.

An example of this work is the determination of the average energies of neutrons. Two types of average energy measuring device were built: a Block and Shon-type device, which determines the thermalized neutron space distribution in a polyethylene block /Fig. 21/; and a Bonner sphere-type device, in which slow neutron detectors are surrounded by moderator spheres of various dimensions. /Spheres of 30, 25, 18 and 15 cm diameter were prepared, the ratios of the counting rates obtained for each pair being characteristic for neutron energies./

In making this sort of measurement one must face the problem that the values of average energy obtained by these devices /the "effective energy" characteristic for the device/ cannot be determined exactly because the parameters in the measuring systems are not completely known. A theoretical approach to this problem led to the determination of the energy response of the Block and Shon system /Fig. 22/, the weighting factor for the average energy formation, and the systematic errors in the values of average energy. Similar calculations were carried out for the paired Bonner-sphere average energy-measuring device as well.

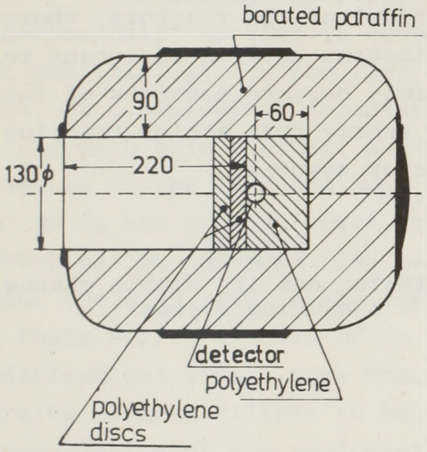


Fig. 21

Cross-section of the Block and Shon average energy measuring device. The space distribution of the thermal neutrons is obtained by plotting the count rate of the BF_3 counter tube as a function of the thickness of the polyethylene discs. The form of the distribution curve is characteristic for the energy of the incident neutrons

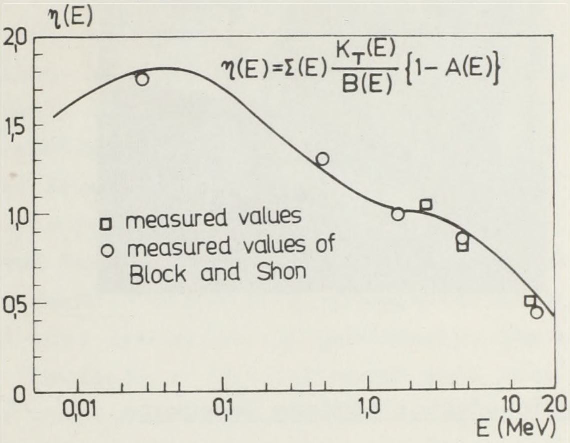


Fig. 22

Sensitivity of the Block and Shon-type average energy measuring device for monoenergetic neutrons. Designations: Σ/E/- total neutron scattering cross-section of moderator, A/E/ - flux albedo, K_T/E/ and B/E/- empiricalcally determined correction factors. The calculations have been verified within the limits of experimental error

The 25 cm diameter sphere prepared for the latter device also served for measuring the rem-doses /Fig.23/. The wide energy range and high sensitivity of this dosimeter make it particularly suitable for measurements of strongly shielded neutron sources /reactor, neutron generator/.

One application has been the plotting of a dose map of the WWR-S reactor using measurements of the dose rates of slow, intermediate and fast neutrons at several hundred places, to show where the shielding required improvement. The modified shielding was able to reduce considerably the dose rate in the reactor hall in spite of the increased power of the reactor.

Practical measurements have shown that a knowledge of the fraction of neutrons belonging to different energy ranges and the average energy of radiation is very important, and calculation of these factors, utilizing neutron spectrum measurements, is in progress. This program has already resulted in the determination of correction factors for numerous dosimeters, and it has been established that personnel dosimeters employing nuclear emulsions for measurement of fast neutrons are not suitable for the radiation control of the reactors, whereas rem-dosimeters have an important role in control, because neutrons of intermediate energy form a high fraction of the reactor spectrum.

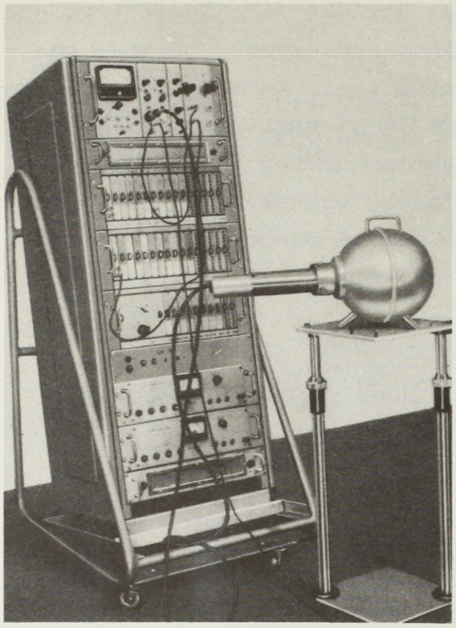


Fig. 23

Rem-dosimeter and its double channel measuring system

Semiconductor neutron detector

The construction of the surface barrier silicon semiconductor detector was a significant technical achievement for the HPD, with use not only in the Department but in other areas of the Institute as well. A computer program allowed the determination of the parameters of a proton radiator aluminium absorber series, which, when placed on the semiconductor detector, gives a response closely fitting the first collision dose curve /Fig.24/. This work has also been the subject of a dissertation.

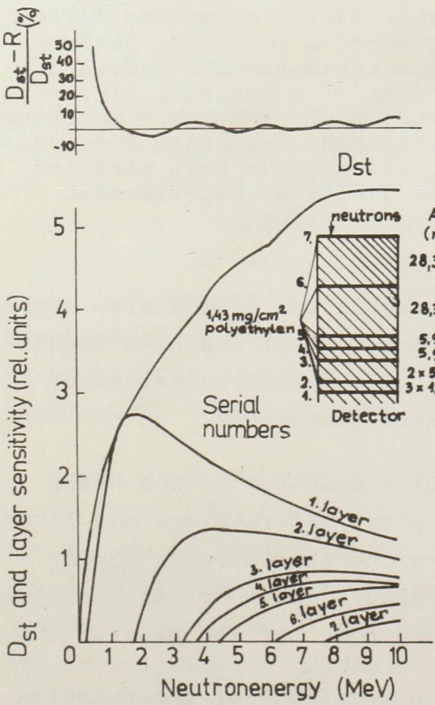


Fig. 24

Section of a laminated proton radiator semiconductor detector: the contribution of the individual foils to the response /R/ and the deviation of the latter from the first collision dose /D_{st}/ curve

Accident dosimetry

The accident dosimeter shown in Fig. 6 is being further developed in the framework of a research agreement with the IAEA. Part of this work is being directed at introducing an improved dosimeter and part at developing more reliable evaluation methods on the basis of the already mentioned calculations of neutron spectra.

Radiobiological experiments

The biological effects of the reactor radiation on mice have been experimentally studied in cooperation with the National Research Institute for Radiobiology for the last seven years. The work included the design, in 1964, of a biological irradiation channel. On the basis of experiences obtained with this channel, an improved variety was constructed in 1968. The diameter of the beam has been increased from 100 mm in the first model to 150 mm in the present model; the distance between zone and the irradiation cavity has at the same time been reduced to 1/3 rd of the initial size. Because the mice used in the experiments receive irradiation perpendicularly to their bodies instead of in the head-tail direction, as previously, these modifications give a more homogeneous irradiation. The increased dose rate permits bismuth filters to be used for varying the neutron/gamma ratio. The cross-section of the equipment and the cage holding the mice are shown in Figs. 25 and 26, respectively.

Neutron dose and spectrum measurements were carried out by activation threshold-detectors so that suitable conditions could be chosen for use of the irradiation channel in subsequent spectrum calculations. Gamma dose rates were measured by thermolinimescent detectors and film dosimeters.

Thermoluminescent /TL/ dosimetry

Initial work on the construction of a thermoluminescent dosimeter was begun in 1967. The TL glass was prepared by the Karcag Glass Factory; the reader unit was constructed in the HPD. The experiences gained with TL-glass were satisfactory, although its fading is more rapid than that ob-foreign glasses. Various types of TL materials from abroad /LiF embedded in Teflon, LiF powder, BeO pellets/ have also been tested, and attempts are being made to improve the home-made glass. Development of the reader device is aimed at improving its signal/noise ratio, its stability and at adapting the laboratory model for service as a prototype device.

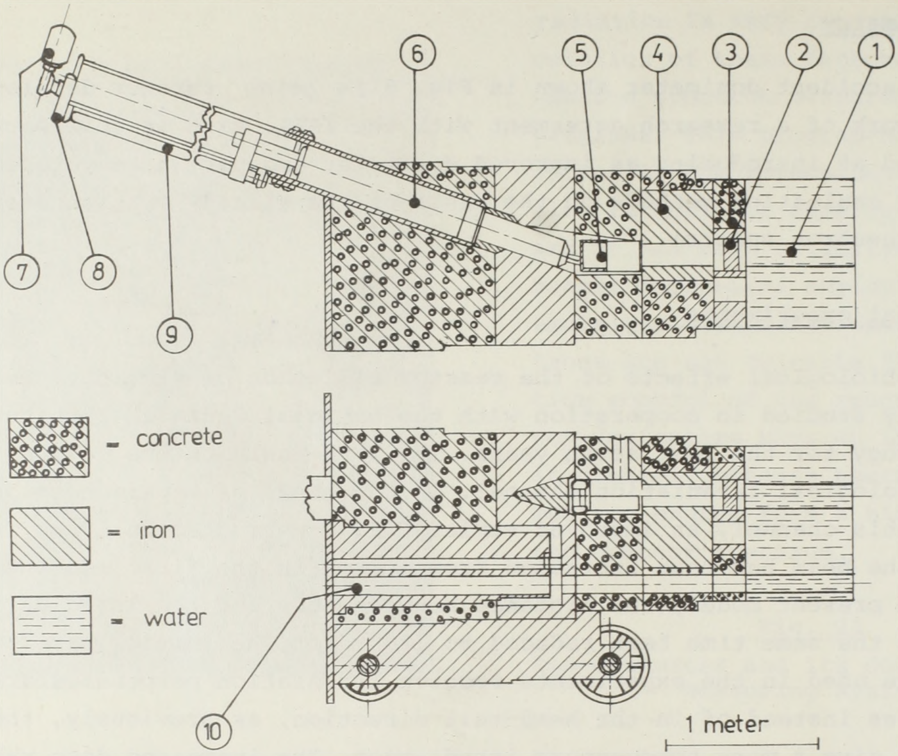


Fig. 25

Cross section of the biological irradiation channel

1 700 mm water seal, 2 bismuth filter, 3 filter holder for the bismuth filter, 4 470 mm iron seal, 5 irradiation cavity, 6 iron plug, 7 plug driving motor, 8 gear-box, 9 screw shaft, 10 tangential channel

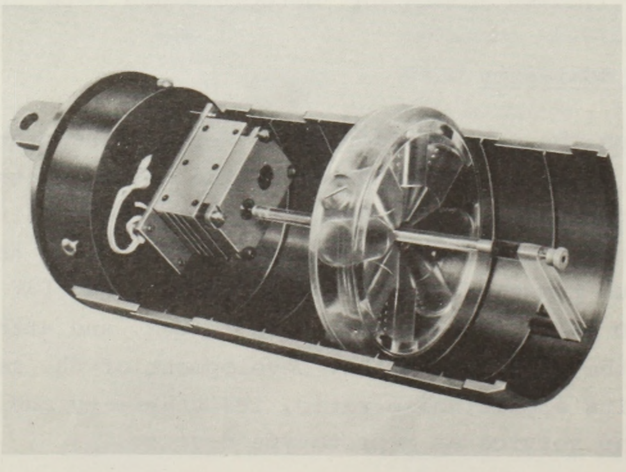


Fig. 26

Irradiation cage made of plexiglass and its rotation equipment: 8 mice can be accommodated

3. COOPERATION, EXTERNAL RELATIONS

The research fields of the HPD are closely connected with problems of biology and medicine. Although biological and medical research is not conducted in the Institute itself there are research constracts with biological and medical institutions.

The HPD has cooperated for several years with the "Frederic Joliot-Curie" National Research Institute for Radiobiology and Radiohygiene in the following fields:

- research in radiotoxicology,
- construction and operation of biological irradiation devices,
- neutron dosimetry.

Research into silicosis is carried out in cooperation with the National Korányi TB Institute and the Research Department of the Mecsek Coal Mining Company.

Studies in the use of whole body counters for medical diagnostical purposes are carried out with the help of the Central Army Hospital.

Systematic control of contamination and incorporation of tritium and personnel neutron dosimetry are carried out by the Department on the basis of contracts with several institutions. Studies have been prepared to help in the planning of several projects, the most significant being that for the environmental control system of a nuclear power plant.

Several guest research workers are working at the HPD on topics concerning the development of health physics services, biological incorporation and neutron dosimetry.

Research workers of the HPD lecture on health physics at the Faculty for Natural Sciences of the Eötvös Lóránd University and the Technical University of Budapest. Students are regularly opting to work in the Department, for the preparation of diploma works in health physics.

The staff of the HPD take part in the work of the Health Physics Section of the Eötvös Lóránd Physical Society by holding lectures, symposia and health physics schools, and by helping in the redaction of the Society's Editions.

4. FUTURE PLANS

Efforts are continually being made to develop the HPD radiation protection service by the introduction of up-to-date measurement techniques. In this context, it is hoped that the use of thermoluminescencent dosimeters for personnel dosimetry can be instituted in the near future. The environmental control network will be extended by installing additional measuring stations, and it is planned to replace the present equipment with more reliable, continuously operating types.

Research will continue in the study of radiation contamination by inhalation and human silicosis. It is hoped that the whole-body counter can now find applications in medical diagnostical investigations. The small animal counters are to be used for research into radiotoxicological and silicosis mechanisms. These experiments will continue to be effected in cooperation with outside biological research institutions. The mechanism of the incorporation of metallic tritides will be studied. One of the most important objectives of neutron dosimetry research is the development of accident dosimetry techniques. This will involve the calculation of the spectra emerging from differently shielded critical systems and the dose received by irradiated perons, and also the development of the thermoluminescent dosimeter. Finally, the research programme investigating the dosimetry of biological irradiation systems is going to be continued.

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Reactor Department
Technical Department
Department for Electronics
Department for Computer Technics

Department for Nuclear Physics
Department for Nuclear Chemistry

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Institute for Isotopes
Nuclear Research Institute
National Institute for Cancer Research
"Gamma" Optical Works
National Board for Measurement Techniques
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